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THE FUTURE ROLE OF BIOFUELS

In the new energy transition

Blucher

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THE FUTURE ROLE OF BIOFUELS IN THE NEW ENERGY TRANSITION

Lessons and perspectives of biofuels in Brazil

The future role of biofuels in the new energy transition: lessons and perspectives of biofuels in Brazil

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CHAPTER 1

BRIEF GLOBAL ENERGY OVERVIEW: TRENDS/SCENARIOS AND THE NEW ROLE OF BIOFUELS

1.1. INTRODUCTION

The aim of this chapter is to provide a brief global overview of energy developments (trends and scenarios) in general, to help the reader to better understand potential future developments in Brazil. And the possible role of biofuels within the paradigm energy shift. In a globalized world with so much interconnected, any impact will resonate beyond national boarders, even in Brazil with its unique conditions for biofuel development.

A fundamental question we need to pose in this shifting scenario is, *what could be the future of biofuels in a new scenario in which no fuel will have the monopoly of oil and gas? How changes in the rest of the world will affect biofuels, particularly in Brazil?* A scenario that will be far more complex, mixed, volatile, and more geographically determined. Biofuels cannot operate on a vacuum, and hence what happen in other sectors, particularly oil, will shape their development. Take, for example, electric vehicles where in some parts of the world, as Europe, could relegate biofuels. In addition, there are two key drivers that will affect the outcome of the energy sector, and consequently biofuels: international response to climate change and environmental sustainability.

1.2. GENERAL BACKGROUND

The energy sector is facing a huge transformation catapulted by growing concern with climate change, global warming, decarbonization, environment, sustainability issues, and political volatility. This is further complicated by Russia's war in Ukraine whose final outcome is difficult to predict. Never before in history has there been so much social and political pressure to change.

The oil sector, and more specifically transport, has not been synonymous of rapid change in the past. In fact, for decades, hardly any significant change took place. For decades, the automobile industry and oil giants, have shared a marriage of convenience. However, the undergoing changes are unparalleled. There are many "unknowns" but undoubtedly such changes represent a paradigm shift with cataclysmic proportions. Huge economic, social, environmental and policy implications, with hundreds of billions of dollars at stage. Such changes represent both huge opportunities and also serious challenges and pitfalls. There is also huge uncertainty with regard to climate change whose enormous implications are difficult to predict; such outcome will have a major global impact, determining future directions and hence will be a key driver for change.

There will be a long energy transition, difficult to predict. But with the right policies, change can be like "a snowball" once started will be difficult to stop. It could work by its own inertia. Given the enormous resources potentially available, the world capacity for scientific and technological developments and innovations, such transition could be faster than predicted.[1] For example, climate warming has been ignored for far too long but now that the world community is beginning to take it more seriously, and social, and political pressures will increase to force change. Climate change is beginning to sink into the young population psychic, despite the fact that for large part of the world population it is a daily struggle for survival and is unwilling or unable to make the necessary sacrifices today for such changes, perceived as something that may happen in a long-distance future.

Within this context, what could be the potential role of biofuels in transport? Biofuels have been around for many decades, and in particular in Brazil and USA, and to a lesser extent in many other countries, hence they represent little technological challenge by comparison, as it is a well-known and proven technology and fuel. The pros and cons of biofuels have been heatedly debated, but on balance, if produced and used sustainably, the benefits far aweigh the negative impacts. Therefore, biofuels represent a considerable advantage over many other emerging alternatives in many parts of the world.

Biofuels have also been the object, as most renewables, of booms and busts. When such alternatives appeared to be economically viable, the price of oil came down dramatically e.g., early 1990s. This time would be different because pressure from climate warming and the environment. Hence, growing concern with climate change, environment, and sustainability, together with social and political pressures, means that this paradigm shift cannot be reversed. On the contrary, it is expected to be accelerated.

But biofuels also have also their negative side that limit their potential. The main one being land competition with food production and the requirement that biofuels need to be environmentally sustainable. The "food versus fuels" (FvF) dilemma has

1 The amount of data generated daily, and the speed in which new scientific data is generated, is such that it is impossible to keep pace except for very specific topics. This poses serious problems.

been the object of heated debate for decades. The debate (e.g., see ROSILLO-CALLE & JOHNSON, 2010; ROSILLO-CALLE, 2018) has been clouded by vested interest, bias, and lack of reliable scientific data. The "FvF" debate needs to consider the intertwined nature of biofuels, land use, food production, food waste, animal feed production, diets, social habits, food distribution systems, policy, and so forth. Advanced biofuels (G2 and G3) could avoid most these problems. It is generally accepted that food and biofuels production can be complementary and, in any case, food production will always prevail.

Biofuels have been around for decades and are an integral part of the fuel mix in the transportation systems. Currently this sector provides between 3-4% of fuel consumption in road transportation, with USA and Brazil as the main producers and consumers, and to a lesser scale in the EU, China, and India (see Figure 1.4). It is an unequal and uneven contribution on a global scale, representing a minuscule contribution in many countries, or none at all. This uneven distribution reflects resource endowment, cultural factors, know-how and policy options. The totality of biofuels is used blended with petrol and diesel in varying proportions, except in Brazil where about 50% is E100.

Another question we need to address is the extent to which the paradigm shift will enhance or inhibit their development, as oil is gradually replaced by other emerging alternatives, e.g., electricity, hydrogen, solar, etc. However, new technological developments such as G2 and G3, e.g., converting cellulose-based biomass to ethanol, will make available large additional amounts of feedstocks in many more countries, at competitive cost over time. Also, we need to ask: should biofuels be promoted as a vehicle fuel or should the focus be on new emerging markets e.g., aviation, maritime transport, or fine chemicals? Biofuels will not be the answer to oil, but they can play a much greater role than has been the case so far in the fuel mix and can make an important contribution to the solution.

During the oil crisis of the 1970s, Brazil showed a great vision by setting up a national ethanol fuel program (e.g., see ROTHMAN, GREENSHIELDS & ROSILLO-CALLE, 1983), a unique project at national level, that served as an international school and was, at the same time, the envy of many countries. This initiative put Brazil in a unique historical footage e.g., a considerable know-how on alternative fuel for transport, as well as technological, agricultural, economic, environmental, and social benefits. Thus, a key question we need to ask is: what will be the new role of biofuels in the emerging energy paradigm in Brazil? What lessons can be applied from its unique historical experience? What lessons are there for other countries? Such questions are addressed in the following chapters.

1.3. ENERGY/TECHNOLOGY TRENDS

Perhaps never in history has there been so much investment and research aimed at finding new alternatives to oil and gas, not only new fuels such as hydrogen, but also engine modifications (electric vehicles) and battery technology. Given the increasing

amount of resources being allocated, technological innovations are growing spontaneously e.g., vehicle batteries, wind power, solar power, hydrogen, new feedstock, to name a few.

It can be stated that renewable energy (RE) in general is growing rapidly, though not necessarily at the pace of potential demand (this will require a fourfold increase), and very unequal around the world. There is a growing shift toward Asia (e.g., China and India), which could overtake the EU. Table 1.1 summarizes the main trends around the world in 2021.

Table 1.1 Summary of main global renewable energy (RE) indicators 2019-2020. Source: REN21 (2022).

Year		2019	2020
Investment on renewables (RE) (power & fuels	Billion $US	298.4	303.5
RE power capacity, including hydro	GW	2,581	2,838
RE capacity (excluding hydro)	GW	1,430	1,668
Hydropower capacity	GW	1,150	1,170
Solar PV capacity	GW	621	760
Wind power capacity	GW	650	743
Bio-power capacity	GW	137	145
Geothermal power capacity	GW	14.0	14.1
Concentrating solar thermal power	GW	6.1	6.2
Green power capacity	GW	0.5	0.5
Ethanol production (annual	Billion litres	115	105
FAME biodiesel production (annual)	Billion litres	41	39
HVO biodiesel production (annual)	Billion litres	6.5	7.5
Countries with biofuels blend mandates	–	65	65

Note: for further details and footnotes see source, page 13. *Please note there are some anomalies due to the Covid-19 pandemic.*

Among the indicators, it calls the attention the total investment going to RE, a firm indication of how investors are taking seriously RE. This trend is increasing rapidly due to recent political considerations such as growing concern with climate change and the Russia-Ukraine war. It demonstrates that RE is reaching maturity.

Annual demand for biofuels (bioethanol and biodiesel in particular) is expected to increase (see below) to around 190 billion litres (B/l) by 2023. Biofuel's production is (and will continue) to be very unequal around the world. Large programs are unlikely, with many small to medium side programs, scattered among many countries, and use primarily as blends. This panorama is unlikely to change fundamentally, with USA and Brazil continuing to dominate this market. It is difficult to predict how this new energy transition will be shaped, as policies are very fragmented around the world together

with volatile geopolitics, reflecting national priorities, cultural and economic factors, resource endowment and know-how.

Two new candidates seem to be particularly strong, i) electrification and ii) hydrogen. None of them are really new as they have been around for a long time (see below). What is new is the huge amount of resources and R&D going into these sectors. Electrification of transport is a real challenge and poses serious problems e.g., how to ensure electricity is generated from RE, and problems posed by such large demand for batteries. In fact, there is a serious danger of creating a monopoly, as with oil, in some countries by relaying too much on electricity. Given the nature and control of rare material by just a few countries, pursuing this option is problematic. There are, therefore, serious economic, political, and environmental unsolved and unanswered problems.

Costs of these alternatives are coming down quite considerably and becoming competitive with conventional fuels, at least in the medium term. Despite the promise of such alternatives, it seems conventional RE (hydro, solar, geothermal and biofuels) will continue to grow rapidly and being a major alternative (IEA, 2021a).

1.4. ENERGY SCENARIOS

There have been many energy scenario predictions but hardly any of them have turned out to be correct. There are a multitude of possible scenarios, but despite improvement of data, energy uncertainly remains an integral part of the world's volatile geopolitics, and a multitude of changing political and economic factors.

One thing seems certain, the automobile of the future will be very different, in which decarbonization, environment and sustainable fuels will play a key role. Such changes represent an enormous challenge to both the automobile and oil industries e.g., technological, environmental, economic, and social. While oil is not going away any time soon it will, progressively, be phased out over time. And many candidates are emerging e.g., electricity, hydrogen, solar, modern biofuels (bioethanol, biodiesel). The future will be dominated by a mixture of fuels with none of them playing a dominant role as oil.

Figure 1.1 shows the changing nature of energy markets, 1900 to 2050. As can be appreciated all RE experience a rapid increase from 2020 and become the main source of energy, with nearly 60%, while fossil fuels declined considerably in the Accelerated Scenario (see below). Decarbonization plays a major role in the increase of RE and a sharp decline of fossil fuels.

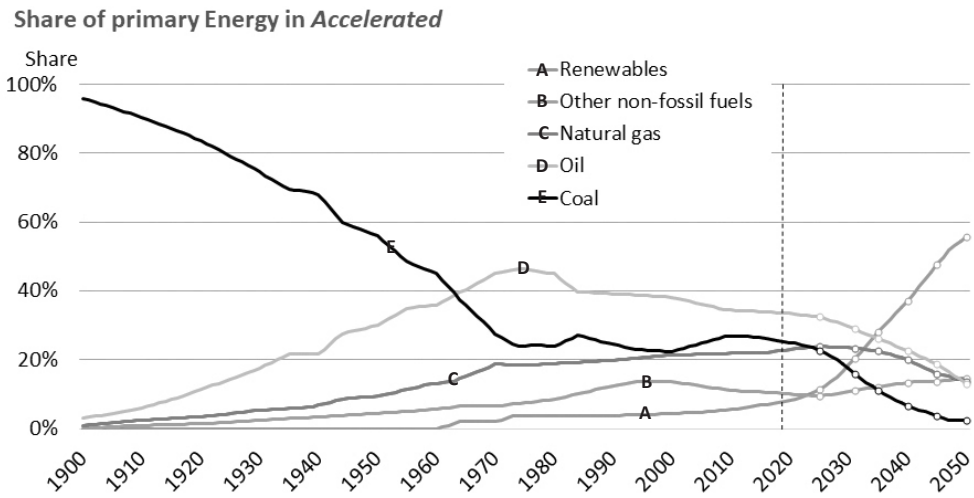


Figure 1.1 Changing nature of global markets: more diverse energy mix, increased competition, and greater customer choice. Source: BP (2022).

The following figure (Figure 1.2) shows in more specific details the role of modern bioenergy according to BP three scenarios: Accelerated, Net Zero and New Momentum, from 2019 to 2050.

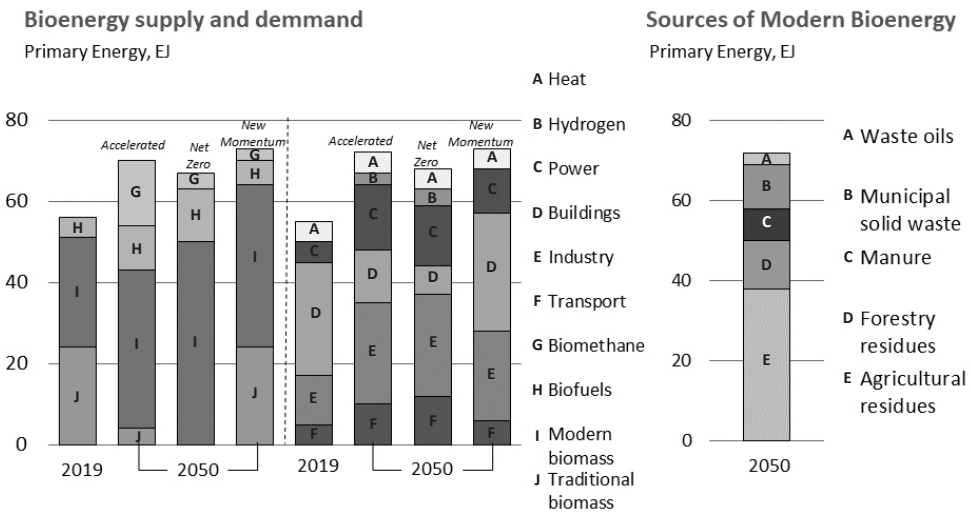


Figure 1.2 Modern bioenergy increases sharply, supporting the transition to a low-carbon energy system. Source: BP (2022).

BP has developed three main energy scenarios: *Accelerated Scenario, Net Zero and New Momentum*.[2] The first two are broadly in line with the Paris Agreement (UN

2 For a detailed assessment of the three energy scenarios, please see BP (2022) Energy Outlook 2022 Edition (www.bp.com/energy/global)

COP25). This requires maintaining temperature below 2°C. Global energy demand measured at the final point of use (total final consumption - TFC) peaks in all scenarios as gains in energy efficiency accelerates. TFC peaks in the early 2020s in the Net Zero, around 2030 in the Accelerated and in mid-2040 in the New Momentum (BP, 2022, p. 17).

Total final energy consumption across all emerging economies growth by about 35% and 5% in the New Momentum and Accelerated and falls by 20% in the Net Zero. In the developed world, contrary, the TFC falls by 25-50% in all three scenarios by 2050s. The share of fossil fuels in TFC declines from around 65% in 2019 to 30-50% in all three scenarios, with the greatest fall corresponding to coal (BP, 2022, p. 39).

It is important to keep in mind that scenarios are largely a function of the level of decarbonization and a multitude of other factors. For details of world energy consumption and projections see also the International Energy Agency (IEA) e.g., IEA (2021a); IEA (2021b); IEA (2021c). There are many others excellent reports and databases on energy e.g. (https://ourworldindata.org/energy-key-charts) where you will find a wealth of excellent energy data.[3]

1.5. BIOFUEL SCENARIOS {CONVENTIONAL AND ADVANCED (G2 AND G3) BIOFUELS}

Figure 1.3 summarizes final use of biofuels demand, based on the IEA (2017) data. The main striking point is the rapid growth of advanced biodiesel and biojet. It is important to state that it is one of many scenarios and hence should be seen as just a *potential outcome*. Scenarios are just potential projections, but despite the discrepancies, all of them point to the same direction: a rapid increase in RE and a steady decline of fossil fuels.

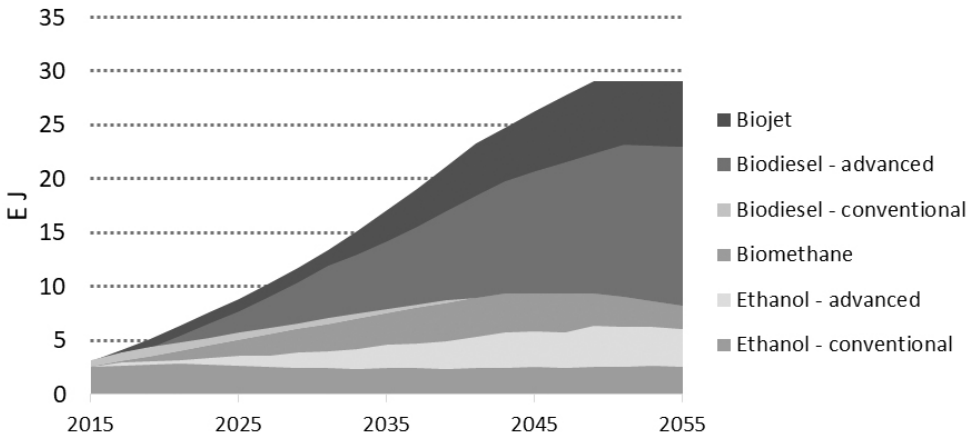
The reason why this Figure 1.3 has been chosen is because data for the latest few years have been distorted by the Covid-19 pandemic. There are three new factors not fully recognized in this figure: i) the rapid growth of electricity and hydrogen, ii) much greater concern with climate change, and iii) growing energy uncertainly and volitivity. This new political reality (caused by Russia's war on Ukraine, among others) could potentially speed up the development of all RE considerably or, contrary, delate it implementation. For example, India is increasing the blending of ethanol with gasoline, primarily to save oil imports due to rising oil prices.[4] And in Europe, which is highly dependent on Russia fossil fuels, politicians are struggling to reduce such dependency with a multitude of options under consideration. Time will tell.

3 See also IEA (2021) Key World Energy Statistics (www.iea.org), IEA (2021) World Energy Statistics and Balances 2021 (www.iea.org)

4 See for example The Times of India, 19th May 2022. India to launch20% ethanol-mixed gasoline (…) (www.thetimesofindia.com)

The evolution of such fuels is strongly dependent on environmental, and climate change and political considerations. If concern with climate warming accelerates significantly, then such scenarios could be quite realistic. Huge resources are being channelled towards this end.

The main biofuels (conventional and modern) continue to be bioethanol and biodiesel. The expected growing role of biojet is somehow a bit controversial as other models give a much lower potential contribution. Much depends on growing demand of such sectors such as aviation and maritime transport. (IEA, 2017). See Section 10.



Notes: Conventional biodiesel referes to crop based FAME biodiesel; Advanced biodiesel refers to a range of advanced biofuels suitable for use in the diesel pool.

Figure 1.3 Biofuels final transport energy demand by fuel type in the IEA 2DS, 2060.
Source: IEA (2017).

As for the type of fuel and geographical distribution, the USA and Brazil continue to dominate biofuel production and consumption, with Europe remaining more or less stable and small increases in Asian markets. A notable increase is advanced biodiesel and biojet fuel. Indonesia is set to be an important player on biodiesel, although it is environmentally controversial because such expansion is based on palm oil plantations (see Figure 1.6).

1.6. ETHANOL FUEL

The following figure (Figure 1.4) shows the geographical distribution of ethanol fuel, and global production in 2021. As can be appreciated, the USA and Brazil are the key players, followed by the EU and some Asian countries (China, India, Thailand). The rest of the world represent a very small market, and in many none at all.

Ethanol was the first candidate as vehicle fuel rather than gasoline. And in Brazil as early as 1925 there was a Federal Law that made compulsory blending ethanol with

gasoline (e.g., see ROTHMAN, GREENSHIELDS & ROSILLO-CALLE, 1983); see also Chapter 6).

Ethanol has been the king as transport fuel around the world. It has been growing steadily, except for 2020 due to the Covid-19 pandemic. It is not expected to expand exponentially as a few countries have the capacity to increase production in large scale and even in Brazil there are questions as its future expansion (see Chapter 5). Total world production of ethanol fuel in 2021 was estimated at 102.2 B/l.

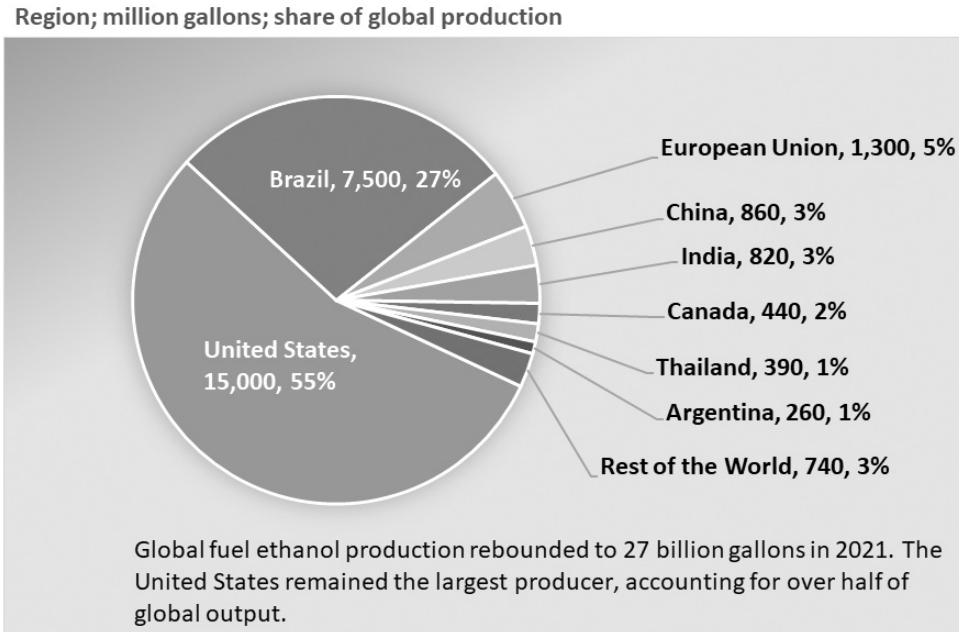


Figure 1.4 Global Fuel Ethanol Production in 2021. Source: RFA (2022).

Note: One USA gallon = 3.785 litres

The USA is the world largest ethanol producer and consumer, representing 55%, followed by Brazil with 27%. Figure 1.5 shows the historical production of ethanol in the USA, rising from almost zero in 1981 to about 56.70 B/l (c.15 B/gal) in 2021. Despite this impressive achievement, current policy indicates the USA does not plan to increase ethanol production in any significant scale in the near future. Unlike USA, Brazil has considerable potential to increase both production and consumption significantly, depending on governmental policy, as discussed in detail in the following chapters.

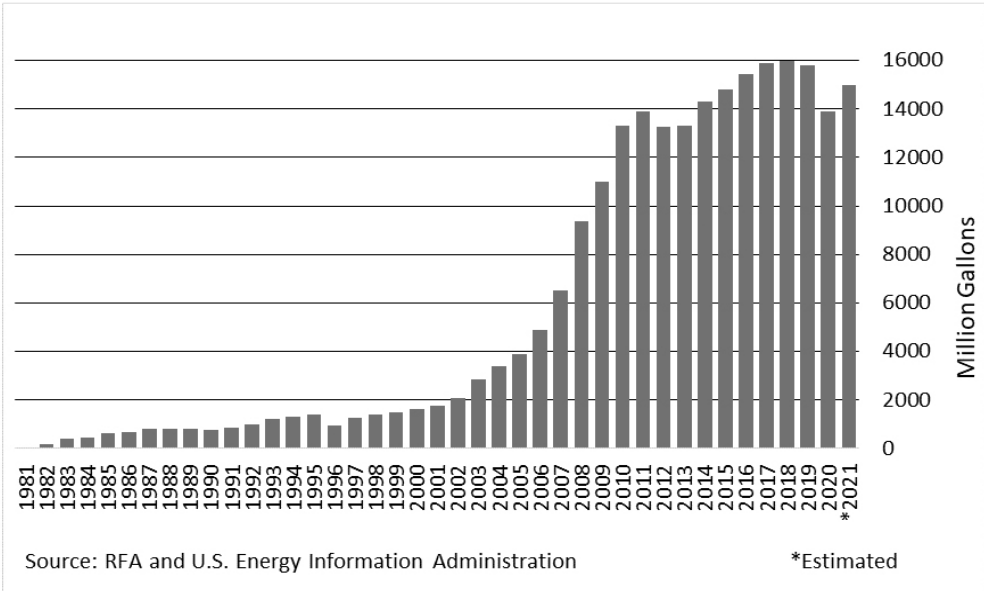


Figure 1.5 Historical U.S. fuel ethanol production. U.S. Energy Information Administration. Source: RFA (2022).

As it has been explained, biofuels are globally unequally produced and used. Many countries are unlikely to produce any at all. A good example is Africa (Sub-Saharan countries), where despite of having a significant potential, there is little prospects in the near future for a combination of political, social, cultural factor, in addition to lack of capital, know-how, etc, as illustrated in Box 1.1.

BOX 1.1: THE ROLE OF BIOETHANOL IN MOZAMBIQUE´S ENERGY TRANSITION BY RUI DA MAIA[5]

The Republic of Mozambique is a country with a vast territory of about 800 000 km2, colonized by the Portuguese, as Brazil, and with a population of around 30 million. Although, there are fundamental differences between the two countries, both can be considered medium-to-low income, where commodities are responsible for a significant share of exports.

Imports consist of fuels, machinery, and agricultural products, representing about 50% of country´s imports. South Africa, China, Emirates, and The Netherlands are

5 Professor at Universidade Técnica de Moçambique (UDM), Mozambique, damaiarui59@gmail.com

the most important partners.[6] The country exports fuels and metals represent nearly 73%, and India, South Africa, and The Netherlands are the most important trade partners. It can be added that South Africa and India are Mozambique´s traditional partners, while China is gradually increasing its importance.

In the energy area, Mozambique has large oil reserves and petroleum plays an important part in its economy. The country has four oil refineries: S&S Refinery, CPF, South Oil, and Southern Refineries (Maëva). Although with important oil reserves and refineries, the country suffers energy supply difficulties particularly in the rural areas due to lack of electricity and other transport fuels.

As for agricultural, the country has a great potential, with fertile land and abundant water, although the country still needs to import basic products. The main reason for the food insecurity of Mozambique relies in the precarious agrarian system where land tenure is the main issue. The present agrarian system can be considered a major obstacle to a more organize and modern agricultural production system, either for food or biofuels production. On top of difficulties associated with land, there is chronic lack of capital, and skills.

The Civil War that followed the Mozambican independence destroyed much of the country´s agriculture and rural infrastructure. The colonial period had its negative consequences, associated with the problems related with Civil War. Although the country has had relatively high growth rates after 1994, this was not sufficient to compensate and rebuilt what was destroyed.

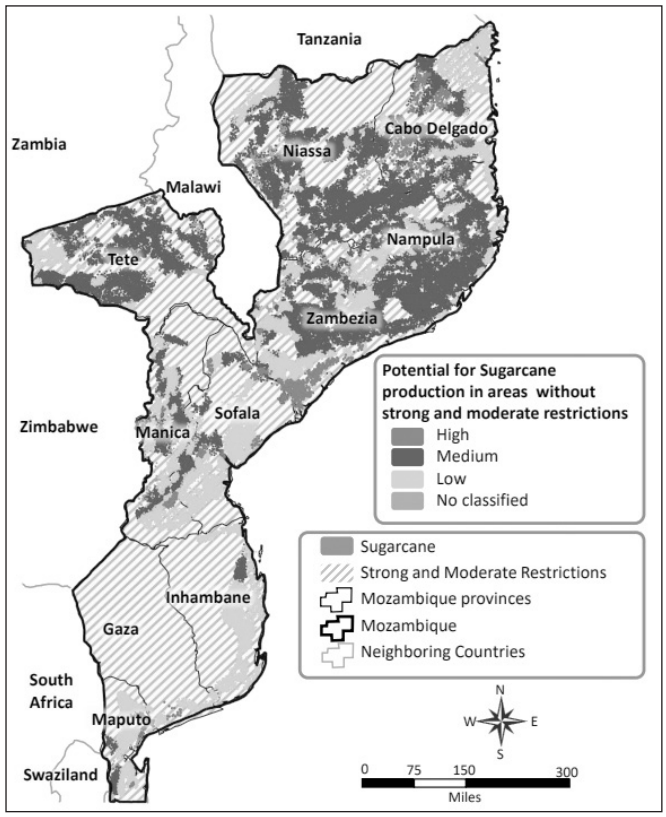
Also, when government authorities considered a biofuel program in the 2000s, crops such as Jatrofa Curcas were considered. As it will be discussed later in this book, the adoption of a non-energy crop for biofuel production is not recommended. Mozambique has experience with sugarcane and should try to use it in any biofuel program.

Sugarcane sector in Mozambique is quite large and organized. The annual sugarcane production is around 3 million tons of cane/year.[7] The Mozambique Sugar Producers Association (APAMO) counts with 4 mills producing around 530,000 tons of sugar and an estimated area of 57,900 ha, directly employing more than 140,000 people.[8] These mills are owned by South African companies.

6 http://portalcomercioexterno.gov.mz/pt/trade-data#:~:text=Os%20principais%20grupos%20de%20bens%20importados%20foram%20os%20Combust%C3%ADveis%20Minerais,USD%20872.6%20milh%C3%B5es%20(12.2%25).

7 FAO (2018)

8 https://i-enterpriser.com/2022/02/27/governo-investe-no-fomento-da-producao-de-cana-de-acucar/



Source: Moreira et al. (2019)

Regarding fuel sugarcane ethanol production, in 2009 it attracted attention from Brazilian investors (UNICA). Basically, three projects were considered, one in the south (120 million litres/year), one in the central region – Manica (100 million litres/year), and one in the North (300 million litres/year). Investments in sugar and ethanol are considered strategic in Mozambique because former colonies are allowed to export to European countries without import taxes.[9] A study conducted by MOREIRA et al. (2019) estimates that 33 Mha are suitable for sugarcane cultivation in Mozambique with medium and high potentials, mostly in the North part of the country (figure below: Source: Moreira et al. (2019)).

Naturally, the role of ethanol production in Mozambique would be more oriented to achieve socio-economic goals, such as increasing exports, population income, and jobs. Therefore, the GHG emissions could be considered a secondary achievement. Another important role of biofuels production would be the introduction of a new

9 https://www2.senado.leg.br/bdsf/bitstream/handle/id/448956/noticia.htm?sequence=1

agrarian system, in which the most important stakeholders could be included. It can be said that, without including the traditional landowners in the negotiation, hardly any one of these goals would be achieved. Therefore, sugarcane ethanol could play an important role in the energy transition in Mozambique.

Food versus biofuels is indeed very sensitive and an important consideration in Mozambique. This may explain, at least partially, FAO doubts in supporting biofuels production and hence its recommendation to use crops that do not compete directly with food production. FAO was probably more concerned with food security than with energy security or jobs, and probably thinks that non-food crops are a safer option when biofuels production is considered.

Mozambique is a country where, despite its considerable biofuel potential, is a good example in which biofuels would not have any future in the short term (5-10 years). This is due to a combination of factors e.g., lack of investment, skill, and political will. Since the social and political situation in most of Sub-Saharan countries are quite similar, one could conclude that this Continent offers little prospects for biofuels in the short term, at least in any significant scale.

Mozambique, as other middle- and low-income economies, doesn´t have means to absorb rapidly the electric mobility. High vehicle prices and lack of necessary infrastructure are the main drawbacks. This transition will probably take several decades. In the meantime, several technologies/fuels will coexist, creating additional pressure in infrastructure and services. Most likely, multinational corporations from China or Europe will start to introduce electric vehicles coexisting with internal combustion engines.

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Table 1.2 summarizes the major feedstocks used in the production of conventional biofuels. For ethanol, the dominant sources are sugarcane in Brazil and maize in the USA. For biodiesel are mainly soybean (Brazil and USA) But feedstocks are becoming more diversified and with the advance of biofuels (G2 and G3) using woody biomass, and oil-bearing plants will be of much greater importance.

The current upheaval in the energy sector, and the consequent potential implication for biofuels, have led the authors to write this book. The prime focus is Brazil whose historical experience has been, and continue to be, a source of inspiration worldwide.

The book is aimed at a wide readership. It examines the key historical development of biofuels in Brazil, current and future. The book investigates these key developments in detail.

The reader interested in biofuels and their wider implications, will be enriched by this unique experience. In a world where fossil fuels will, eventually, be phased out, biofuels represent a viable partial alternative in many countries. Biofuels represent a world of possibilities.

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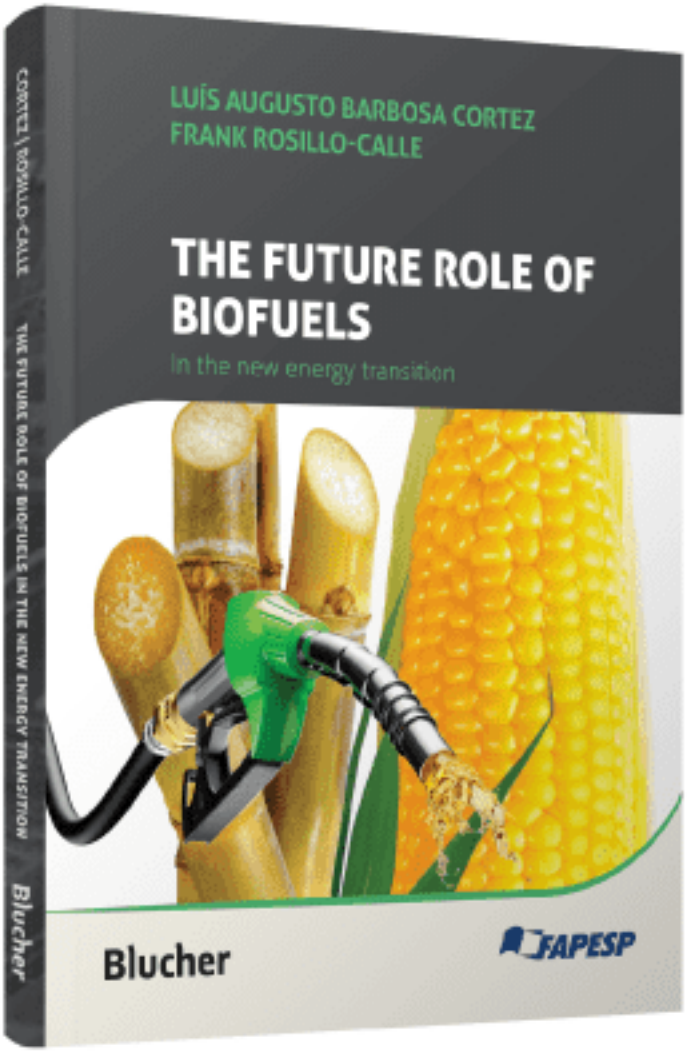

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